

## Title: CubeSub

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This presentation introduces and discusses the development of the CubeSub submersible concept, an Autonomous Underwater Vehicle (AUV) designed around the CubeSat satellite form factor. The presented work is part of the author's MSc thesis in Aerospace Engineering at the Royal Institute of Technology, Stockholm, Sweden, and was performed during an internship at the Mission Design Division of the NASA Ames Research Center, Moffett Field, CA.

Still in the early stages of its development, the CubeSub is to become a submersible test-bed for technology qualified for underwater and space environments. With the long-term goal of exploring the underwater environments in outer space, such as the alleged subsurface ocean of Jupiter's moon Europa, a number of technology and operational procedures must be developed and matured. To assist in this, the CubeSub platform is introduced as a tool to allow engineers and scientists to easily test qualified technology underwater.

A CubeSat is a class of miniaturized satellite built to a standardized size. The base size is 1U (U for unit), corresponding to a  $100 \times 100 \times 113.5 \text{ mm}^3$  cube. A 1U CubeSat can in other words easily be held in one hand. Stacking units give larger satellite sizes such as the also commonly used 1.5U, 2U and 3U. The CubeSat standard is in itself already well established and hundreds of CubeSats have to date been launched into space. Compatible technology is readily available and the know-how exists in the space industry, all of which makes it a firm ground to stand on for the CubeSub.

The rationale behind using the CubeSat form factor is to make use of this pre-existing foundation, making the CubeSub easy to develop, modular and readily available. It will thereby aid in the process of maturing the concept of a fully space qualified submersible headed for outer space. As a further clarification, the CubeSub is itself not meant for outer space, but to facilitate development of such a vessel.

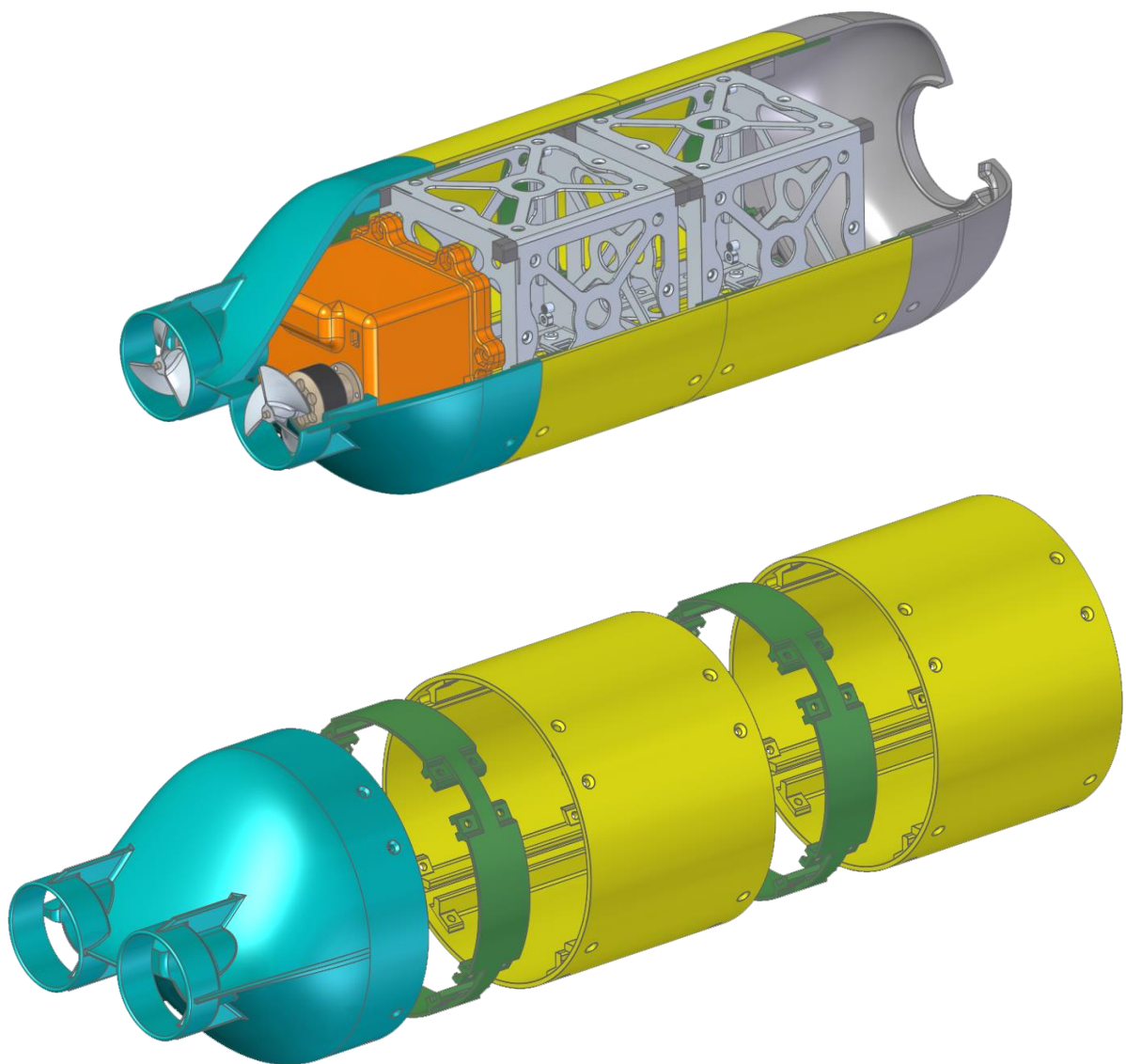
Along with its uses as a testbed, the CubeSub also holds the potential to become a useful tool for exploration and experimentation here on Earth. A highly standardized system utilizing well-known hardware can reduce the cost and required work load for researchers wishing to perform experiments and exploration. Users could design sensors and experiments to comply with the already well established CubeSat standard, which are then carried by the CubeSub to the region of interest. This in turn means that the end users can focus more on formulating the experiment itself and less about how to get it where they want it.

The CubeSub is designed to be built up by modules, which can be assembled in different configurations to fulfill different needs. Each module will be powered individually and intermodular communication will be wireless, removing the need for wiring. The inside of the cylindrical hull will be flooded with ambient water to enhance the interaction between payloads and surrounding environment. The overall torpedo-like shape is similar to that of a conventional AUV, slender and smooth. This is to make for a low drag, reduce the risk of snagging on surrounding objects and make it possible to deploy through an ice sheet via a narrow borehole or navigate in tight areas. To keep costs low and further accelerate development, rapid prototyping is utilized wherever possible. Full-scale prototypes are being constructed through 3D-printing and using COTS (Commercial Off-The-Shelf) components. 3D-printing is used both for the largest hull components and the relatively small and delicate propellers. Arduino boards are used for control and internal communication.

Modules required for basic operation have been designed, prototyped, and tested. By performing tests in a pool it was found that the basic concept is sound and that future improvements include better controllability, course stability and waterproofing of electrical components. Further development is needed to make the CubeSub usable for its intended purposes. The largest gains are expected to be found by software development and improved controllability.

.The presentation will treat the details of the technical design, the different subsystems and modules, development and testing results as well as the future outlooks.

Pictured below is a small configuration of the CubeSub, in the first picture holding two empty CubeSat chassis and in the second picture an exploded view of the hull and thruster module. In the exploded view the standardized interface rings (green) can be seen between the modules (yellow and blue).



#### 10.4 Autonomous Underwater Vehicles (MNT.2, MNT.8, 10.1)

500 word minimum; 1000 word maximum; 2 page maximum inclusive of figures and equations.

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